INTRODUCTION
Today there are over 1.7 million amputees living in the US (Amputee Coalition) and the majority of these patients suffer fit-related disorders ranging from discomfort to skin ulcers. However, recent advances in post-processing of computed tomography (CT) data offer new opportunities to quantify socket fit. In this paper, we present new data that quantifies socket fit for below knee amputees using data derived from CT scans, including thickness of liners and gaps between liner-socket, and liner-stump. This descriptive geometric analysis is an attempt to initiate a long-term socket fit screening protocol at different times within a year in an effort to accurately quantify the seasonal stump volumetric changes of lower extremity amputees.

METHOD
CT scans from 19 below-knee amputees (15 male, 4 female, ranging in age from 34 years to 79 years) were analyzed. Measurements were taken at 10mm increments from the base of the socket based on a protocol with visible tantalum markers (Fig. 1). The CT data were processed removing metal artifacts for each patient and the following distances were identified and measured circumferentially around the stump using MIMICS software (Fig. 1): A: socket thickness (solid part), B: first liner thickness (some patients have several liners), C: Gap between liners (if it exists), D1: Second internal liner in touch with the tissue. From the measured data for each patient, the mean distances per slice s (Ap,s, Bp,s, Cp,s, D1p,s) were then computed. The mean patient distances (Ap, Bp, Cp, D1p) were then estimated by averaging over all slices, e.g., Ap = (1/n) (Ap,1 + Ap,2 + … + Ap,n). The value of n reflects the number of slices available for the regions of measurements.

RESULTS
Table 1 reports the mean, median, standard deviation, and range for the mean patient distances (some data was applicable to fewer than 19 patients). For example, the mean for B is (1/15) (A1 + A2 + … + A15). No obvious relations between mean distance per slice and slice position (i.e., Ap,s, Bp,s, Cp,s, D1p,s vs. distance from bottom of socket) were observed; for brevity, this detailed data is not presented here.

DISCUSSION
Distance A has a relatively low variation; this is not surprising, because it represents the thickness of the socket wall, which is relatively standardized. It is however, noteworthy that there is high variation in distance C, and moderately high variation in distances B and D1. This stresses the need to always assess the thickness of liners and their proper fitting given that they might result in high-pressure areas or unwanted gaps between liners. The variation in liner thickness suggests that liners are significant means of interface mechanics of the socket-stump complex.

CONCLUSION
These measurements are not really comparable to commonly cited values from experts or manufacturers because of the difference in direct versus indirect measurement modalities. With the exception of another CT study (Vannier, 1997) all other studies measured the non-donned stump or used obtrusive sensing technology that interfered with the measured stump volume or compressed areas of interest. A limitation of our technique is the irradiation exposure. As a remedy we chose to scan only the areas of interest with the lowest exposure possible (< 0.6mSv per scan), even skipping some stump zones of no interest.

CLINICAL APPLICATIONS
This technique promises to introduce a new standard in measuring socket fit that does not interfere directly with the measurement.

REFERENCES